Report to the
Office of Environmental Quality Control
State of Hawaii Department of Health

DETERGENT PHOSPHATES IN HAWAII

Prepared by
Doak C. Cox, Ad Interim Director, Environmental Center
L. Stephen Lau, Acting Director, Water Resources Research Center
John P. Craven, Dean, Marine Science
University of Hawaii

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This is written in response to your request of 4 May 1971 for information on the relationship between presently used phosphate-based detergents and water quality problems in Hawaii. As you are well aware, organized citizen groups anxious to further the cause of improving the quality of our environment have, on a nationwide basis, singled out phosphates as the number one cause of water pollution. In this they have been encouraged by articles in the popular press (Steinman, 1971), which traditionally thrives on disaster and hence is often more sensational than factual. Thus it is particularly important that the role of detergent phosphates in Hawaii's coastal water quality problems be fully understood before any assumption is made that such problem can be resolved by legislation limiting the use of phosphates in detergents. To contribute to such an understanding without undertaking a comprehensive textbook on the subject, discussion is hereinafter directed to the following aspects:

1. Phosphates and detergent formulations.
2. The role of phosphorus in the ecosystem.
3. Water quality as a function of detergents and nutrients.
4. Sources and concentration of phosphorus in Hawaiian waters.
5. Control of phosphate concentrations in water.
6. Conclusions.

1. Phosphates and detergent formulations

Detergents consist essentially of "builders" and surfactants. Other ingredients may include brighteners, perfumes, anti-redeposition agents, and enzymes. The functions of the builder are to supply alkalinity necessary for effective soil removal and to sequester ions that would counter the effectiveness of the surfactant (Hammond, 1971). The principal builders used in detergents are phosphate compounds, usually sodium tripolyphosphate, tetrasodium pyrophosphate, tetrapotassium pyrophosphate, or in special cleaners such as trisodium orthophosphate (Purchase, 1971).

Objections to the discharge of phosphates, such as discussed in subsequent sections, and threats to prohibit or limit the use of phosphate by legislation have led the detergent industry to search for satisfactory substitutes. Initially, nitrilotriacetate (NTA) seemed a likely substitute for phosphate as a builder (Reuss and others, 1970), although NTA is hydroscopic and tends to make the commercial detergent lumpy. However, it soon developed that NTA may have teratogenic effects, especially in combination with heavy metals, and its use was suspended in December 1970 (Hammond, 1971) pending further toxicological studies. As pointed out by Ryther and Dunstan (1971) NTA substitutes nitrogen for phosphorus and hence would encourage algal growth in any water where nitrogen rather than phosphorus is the limiting nutrient.

Non-phosphate detergents are now being manufactured and publicized to take advantage of the public misconception of phosphate as a water pollutant. Such formulations use carbonates and silicates, often called "precipitating builders" because they combine with calcium ions in hard waters forming precipitates that may build up in the cloth being washed. Such detergents are highly alkaline (pH between 10.5 and 11 vs. pH between 9 and 10.5 for phosphate detergents). Some detergents manufactured with metasilicates had pH higher than 11 and were found to cause skin corrosion and eye damage. These were banned in March 1971 (Hammond, 1971; Steinman, 1971). Silicate builders can also damage the porcelain bowls used in washing machines. Moreover, questions have been raised as to the washing efficiency of the current non-phosphate detergents (Hammond, 1971; Purchase, 1971). Because of the range of types of soil to be removed, such questions are difficult to settle by laboratory tests.

Conclusion

At the present time there appears to be no viable alternative to the use of phosphate-based detergents that does not present some health or environmental hazards. The use of ordinary household soaps or castile soaps would be adequate for cleansing purposes because of the softness of the water supplies in Hawaii; however, such products themselves contain approximately 20% phosphates. Reverting to the use of "Grandma's" lye soap presents the same alkaline hazards as found with carbonate and silicate-based detergents. Thus there would be considerable detriments associated with the banning of detergents. It is therefore important to examine in some detail the phenomena associated with phosphates in the aquatic environment.

2. Phosphates in the Ecosystem

Phosphorus is one of a number of elements essential to the growth of aquatic organisms. In the presence of a source of carbon, especially carbon dioxide, it ranks with nitrogen as a major fertilizer of plants. However, micro-nutrients such as iron, molybdenum, magnesium, sodium, manganese, boran, cobalt, and vanadium (Ferguson, 1968; Hutchinson, 1969) are among the growth stimulants which must be present if the utilization of nitrogen and phosphorus is to proceed.

Aquatic plants, such as algae, use nitrogen and phosphorus in various ratios depending upon the species and the plantitude of nutrients. "Luxury consumption" of N or P may occur in the presence of an excess of one or the other but normally the algal cell uses 8 to 15 atoms of nitrogen to 1 atom of phosphorus (i.e. N/P ratio = 8/1 to 15/1).

The concentration of N at which it is limiting to algal growth is customarily taken as 0.10 mg/l (milligram per liter). The corresponding value for P is 0.01 mg/l.

Objection to Phosphates

The objection to phosphorus is that when it is in excess of the amount needed to tie up all available nitrogen (e.g. N is appreciably less than 8 for every 1 P), and degradable organic matter is sufficient to reduce dissolved oxygen to near anaerobic levels (e.g. 1 or 2 mg/l D.O.), organisms such as blue-green algae appear. These organisms are capable of taking nitrogen from the atmosphere and so may grow to the limit of available phosphorus. This may lead to heavy blooms of algae which render the water unsightly and unsuitable for most beneficial use; and which upon death decompose anaerobically, with resultant foul odors.

The Phenomenon of Eutrophication

The term "eutrophication," which means literally "nutrient rich" has been widely adopted to describe the consequences of over-fertilization of confined waters such as lakes, ponds, and poorly flushed estuaries. In nature most lakes are initially "nutrient poor" (oligotrophic) and became eutrophic with time and with discharges of nutrients either from land runoff or human waste discharges. Such nutrients are recycled in the ecosystem and the eutrophication process is irreversible by nature.

Most oligotrophic lakes are phosphorus sensitive (i.e. have an excess of nitrogen in comparison with phosphorus). Notable exceptions include Lake Tahoe (California-Nevada) which is nitrogen sensitive.

Eutrophication is likely first to be indicated by augmented growth of phytoplankton, even algal blooms, or increased growth of high plants. The further consequences may be held beneficial, as in the case of increased production of fish, or deleterious as when algal mats decay causing odor problems or exhausting oxygen supplies and causing fish kills (Larkin and Northcote, 1969). The relative importance of various nutrients in causing eutrophication in lakes has been much debated. The most recent conclusions seem to be that phosphorus is generally the most limiting element and is, further, the easiest to control (Likens and others, 1971).

In streams there may be similar effects from nutrient enrichment, though generally they are less marked because of the continuous dilution and mixing of the waters and, except in large rivers, less likely to involve phytoplankton growth (Hynes, 1969).

In estuaries, where the circulation may be restricted, as it is in lakes, the effects are in general similar to those in lakes though differing in detail because of the ranges from fresh water to salt water and the resulting peculiarities in circulation patterns and biota (Ketchum, 1969; Carpenter, Pritchard, and Whaley, 1969). The nutrients in estuaries may be supplied principally from influent streams or from ocean water drawn in by the estuarine circulation (Ketchum, 1967).

Although streams and sewers may cause significant enrichment of the ocean locally at their mouths, their contributions of nutrients have little consequence in the open ocean. Emery and others (1955) have estimated that on a world basis the rate of use of phosphorus by phytoplankton (1.3×10^9 metric tons/yr) is nearly a hundred times the rate of supply from land sources (1.4×10^7 metric tons/yr). The major part of the phosphorus used comes from the reserve of phosphorus in the ocean (1.2×10^{11} metric tons, nearly a hundred times the annual use). The rate of supply from the land is nearly balanced by the rate of loss to sediments (1.3×10^7 metric tons/yr).

Most of the nutrient content of the oceans is, however, in the lower layers to which no light penetrates and in which there is no primary productivity. As has long been recognized, the surface layers of the ocean are deficient in nutrients, including phosphorus, and as has been shown by Ryther (1959), the productivity of most open ocean areas is comparable to that of deserts on land, the limitation in the ocean being due to nutrient deficiency and that in the land deserts to water deficiency. The return from nutrient reserves to phytoplankton production occurs in relatively restricted areas of upwelling in the ocean, none of these areas being in the vicinity of Hawaii.

Further, as pointed out by Ryther and Dunstan (1971), the *surface layer of the ocean, besides being nutrient deficient, has nitrogen to phosphorus ratios so low that nitrogen is the limiting element to bio-stimulation rather than phosphorus.*

Okun, in testimony before the Federal Trade Commission (1971) has summarized the conditions necessary for eutrophication to occur as follows:

1. The body of water must be slow-moving, so that it retains the nutrients. Therefore, eutrophication is generally confined to lakes and estuaries.

2. The body of water must receive all of the nutrients necessary to the growth of algae, principally carbon, nitrogen, and phosphorus, along with other trace nutrients. Phosphorus, in the form of phosphates, is generally, but not always, the limiting nutrient.

3. The body of water must receive sufficient solar energy for photosynthesis. For this reason shallow or clear bodies of water are more likely to become eutrophic than deep or turbid waters.

Okun estimates that about 55% of the nation's population resides in cities whose municipal wastewaters discharge into rivers on the ocean, where there is no danger of eutrophication. Designated in this category were cities including New York, Pittsburgh, St. Louis, Chicago, and Los Angeles. However, he notes that communities where wastewaters may stimulate eutrophication of receiving lakes or estuaries, *eutrophication would continue even if all the phosphates were removed from detergents*, because of the remaining residual from human wastes and urban runoff.

3. Water Quality as a Function of Detergents and Nutrients

The principal source of detergent-related phosphorus is wastewater from the public sewers. Treated sewage effluents (secondary treatment) typically contain about 10 mg/l of phosphorus and 40 mg/l nitrogen. Primary (settled) effluent may contain twice these concentrations, but in any case the N/P ratio is of the order of 4/1, indicating a nitrogen rather than a phosphate deficiency. Generally only about 50 percent of the phosphorus in sewage comes from detergents, although for some estuaries receiving waste waters from large metropolitan areas the phosphate fraction from detergents has been estimated as high as 70 percent (Hammond, 1971). The remainder comes from the food supply of humans, including garbage discharged to the sewer via household garbage grinders.

Thus if *all* phosphate associated with detergents were eliminated the remaining phosphorus would still be in scale with available nitrogen (i.e. N/P=8/1) and *the growth potential of the wastewater would still remain*. Inasmuch as essentially no sewage today is discharged under conditions that permit D.O. to sink to a level for favorable use of excess P with atmospheric nitrogen, the net effect on the growth potential of the sewage itself of banning phosphates in detergents would be zero. The question then reduces to whether the excess P by and say an 8/1 N/P ratio is an important factor in a receiving water which is itself phosphorus sensitive (i.e. has an excess of nitrogen).

Of the phosphates reaching the ocean from the land, Ferguson (1968) has estimated that between 25 and 50 percent may be derived from detergents. At Lake Tahoe, McGauhey and Dugan (1971), found runoff from developed land areas in the Basin to contain the same amount of phosphorus as the sewage in the same area (i.e. 50% derived from sewage). In general it is held that detergents account for about 50 percent of the phosphate in wastewaters in the United States, some estuaries for wastewaters of large metropolitan areas running as high as 70 percent (Hammond, 1971).

Artificial sources of phosphorus in wastewaters and streams, in addition to the detergents are other organic components in sewage, include some industrial wastes, feed lot runoff, and excess fertilizers. Phosphorus is naturally derived from the weathering of rocks, and the degradating of organic materials, especially plant leaves, in which phosphorus is concentrated.

4. Phosphates in Hawaiian Waters

Estuaries and the Ocean

There have been several studies of estuarine and coastal waters yielding reliable data in recent years. Probably the most studied area has been that of Kaneohe Bay where data have been collected from time to time since at least the year 1952. Table 1, summarizes some of these data and the conditions prevailing at the time of observation, together with similar data for other areas in Hawaii.

From the data shown in Table 1 for Kaneohe Bay it seems evident that an increase in PO_4-P in the Bay is identifiable over the sewer outfalls and increased during the 1965 year of study at specific locations in the Bay. Banner and Bailey (1971) have called attention to the increase in the PO_4-P context in the region over the municipal sewer outfall from Piyakarnchana's original value of 0.010 in 1965 through Bathen's value of 0.044 in 1966-67 and the mean value of 0.08 reputed by Young in 1968-69, to an average (unpublished) of 0.124 mg/l obtained in 1970 by Caperon and Cattell.

It should be noted that values in Table 1 for all areas except Kaneohe Bay are in terms of total P rather than PO_4-P. The ratio of reactive soluble phosphate phosphorus (PO_4-P) to particulate phosphorus may vary greatly, hence no ready conversion can be made from values of PO_4-P to total P. Bathen has noted that a typical mean value for PO_4-P concentration in the top 10 meters of the open ocean off Kaneohe Bay is 0.0013 mg/l. This is an order of magnitude less than the offshore values for total phosphorus found by Ultramar (1968), which varied from 0.0146 off Koloa, Kauai to 0.0332 off Kahului, Maui.

Gordon (1970) shows graphically the variation in PO_4-P and total P with depth at oceanic station Gollum, 47 km due north of Oahu. Although the values are difficult to scale accurately from the curves, it is interesting to note that the N/P ratio is about 5/1, indicating that the ocean in that area is nitrogen poor; hence, reduction in phosphorus discharge to the ocean would serve no purpose. From this, and data presented in a preceding section it *may be concluded that the N & P balance is more important ecologically than any absolute value of phosphorus concentration.*

Streams

Although there has been an increase in phosphorus concentration in Kaneohe Bay since sewage discharges began it must be remembered that the land activities of man likewise have increased during the same period. McGauhey and Dugan (1971) found at Lake Tahoe that nutrient discharges from developed land was twice that from undisturbed forested land, and from 3 to 10 times greater during the period of active land development. Obviously the evergreen forests of the high Sierras are different than the tropical vegetation of Hawaii, but the latter should contribute much greater recycling of phosphorus because of its greater yield of organic matter. Therefore, the phosphorus and nitrogen contribution of streams becomes a matter of interest.

A survey of 11 streams discharging to Kaneohe Bay (OWQP preliminary report, 1971) shows an average value of total N = 0.24 mg/l and PO_4-P = 0.022 mg/l, i.e. an N/P ratio of about 10/1. However, 5 of the 11 streams showed N/P ≃ 10/1, and 6 showed an N/P ratio of about 5/1, indicating (where the flow rates are considered) that about 55 percent of the flow into Kaneohe Bay was nitrogen poor or "nitrogen limited" rather than "phosphorus limited" in its potential to support algal growth. Previously Young and others (1969) reported mean concentrations of PO_4-P of 0.01 to 0.10 mg/l in eight of these same streams.

Tenorio and others (1969) reported results for the Pearl Harbor Region. Kalawao and Waimalu streams contained about the same concentration of phosphorus as Kaneohe Bay (i.e. less than 0.01 mg/l). However, Waikele and Waiawa streams, farther west, yielded values of 0.6 to 1.2 mg/l-P. The difference between the two sets of streams may result from agricultural runoff or sewage discharge; both of which reached the western streams. Young and Chan (1970) reported soluble phosphate in various sewage treatment plant effluents at concentrations ranging from 6.1 to 12.2 mg/l-P. Thus Waikele and Waiawa streams carried a PO_4-P concentrations one order of magnitude less than sewage treatment plant effluents.

Relating runoff to sewage discharge in Kaneohe Bay, Young et al. (1969) showed that the nutrient load in Kaneohe Bay at that time was principally influenced by sewage sources. Streams contributed an average N and P load of approximately 116 lbs/day and 16 lbs/day, respectively. In contrast the two sewage treatment plants discharged 900 lbs/day N and 300 lbs/day P. Here it is interesting to note that the N/P ratio in streams was about 7.3/1 and about 3/1 for sewage. Thus there is an excess of phosphorus in both the streams and the sewage which could be utilized in the Bay or the ocean under prevailing aerobic conditions only if these receiving waters were phosphate limited (i.e. had an excess of nitrogen over phosphorus).

Conclusions

Because evidence indicates that the marine waters are likewise nitrogen limited, no useful purpose would be served by outlawing phosphates in detergents, whereas harm to water quality would result from substituting a nitrogen compound such as NTA for PO_4-P in detergent formulation.

5. Control of Phosphates in Water

Rationale

There are three principal reasons for limiting phosphate concentration in waste waters which are evident today.

1. The control of eutrophication potential of a discharge.

2. Conformity to arbitrary standards

3. Response to an artificially generated popular belief that phosphates are the number one cause of water "pollution."

A fourth reason which has manifested itself in Suffolk County, New York is the elimination of evidence of sewage effluent in the drinking water supply. In this case the foaming of the surfactant rather than the phosphate component of the detergent formulation was the objection and so the use of synthetic detergents was recently prohibited.

Of the three reasons listed above the third is an outgrowth of a popularized misconception of the first. Since the detrimental eutrophication effect of phosphates became generally recognized,there has been a great deal of agitation to ban the use of phosphates in detergents-based phosphates (Reuss and others, 1970). Pursuant to a combination of specific instances of eutrophication problems and the enthusiasm of a misinformed but environmentally activist electorate, Canada has already limited the phosphate content of detergents, and Indiana, Chicago, Detroit, Akron, Buffalo, and Miami have limited the phosphate percentages of detergents in 1971 and called for a total cessation of phosphate detergents before the end of 1972 (Steinman, 1971). The cumulative effect of such legislation, unfortunately, is to generate a trend which is easy to follow elsewhere without first evaluating the rationality of such action under local circumstances.

Situation in Hawaii

The situation in Hawaii is most closely related to conformity to standards. Here state water quality standards were adopted through public hearings held in 1966 and 1967. At that time the only phosphorus values available pertained to phosphates (PO_4-P). The values adopted in the standards were, however, expressed in terms of total phosphorus and are: 0.02 mg/l in Class AA waters; 0.025 mg/l in Class A waters; and 0.030 mg/l in Class B waters.

It seems evident that the standards adopted are more related to the concentrations at which phosphorus is limiting to algal growth than to the natural conditions existing in Hawaiian waters. In fact, data amassed since 1966-67 (see preceding section) cast considerable doubt upon the ability of nature herself to meet the standards. This, however, is not an uncorrectable shortcoming of the standards. Because of the interconvertability of (soluble reaction) phosphate phosphorus and particulate organic phosphorus, the use of total-P rather than PO_4-P seems quite appropriate. However, the appropriateness of the particular values selected as tolerances is quite questionable.

Removal of Phosphates

Phosphate removal in sewage treatment is presently achieved by chemical precipitation, the cheapest method being one which renders phosphates insoluble by raising the alkalinity (pH) of the water. In the much publicized advanced wastewater treatment plant of the South Tahoe Public Utilities District, the phosphate content is reduced to concentrations of 0.001 to

0.002 mg/l. In some instances iron salts or alum may be the most desirable coagulant, depending upon the overall treatment process and its desired objectives. Biological systems based on luxury uptake by activated sludge and high productivity algal ponds have also been utilized. An advanced waste treatment system providing for nutrient removal, including phosphorus, is currently under construction at the Ahuimanu Sewage Treatment Plant on Oahu. This is the only plant in the state with specific provision for nutrient removal. As a general rule among existing treatment facilities in the state, those discharging into natural watercourses provide some degree of biological treatment, while those discharging into coastal waters provide at least primary treatment.

6. Conclusions

There appears to be no viable alternative to the use of phosphate-based detergents that does not present some health or environmental hazards. The use of ordinary household soaps or castile soaps would be adequate for cleansing purposes in Hawaii because of the softness of the local water supplies; however, such products themselves contain approximately 20% phosphates. Reverting to the use of "Grandma's" lye soap presents alkaline hazards such as are found with the carbonate and silicate-based detergents presently being marketed to capitalize on the public concern over phosphates. Thus there would be considerable detriments associated with the banning of detergents, particularly in view of the limited effect such action would have in eliminating phosphates where they do present a problem of water quality management.

If phosphate removal is necessary to meet water quality standards, or the objectives of such standards, nutrient removal will still be a required wastewater (sewage) treatment process regardless of the elimination of detergent phosphates at the source. Moreover, the most economical current methods of phosphate removal are essentially economically independent of the phosphate concentration at the levels prevailing in wastewaters. Therefore, little but expense and problems of cleansing would accrue from removing part of the phosphorus by legislation and part by technology.

In the specific case of Hawaii, with which this report is concerned, the state water quality standards, even if they were amended to sanction the total phosphorus concentrations observed by Ultramar (1968) in offshore waters (see Table 1), would still make it imperative that discharges of sewage having high phosphorus concentrations, whether derived from detergents or other components, either be treated by advanced methods to remove the nutrients or be sanctioned by zones of mixing. In waters close to shore, particularly in estuaries of limited circulation, high-nutrient discharges should be avoided because of the deleterious effects of eutrophication in such waters. Zones of mixing cannot in any case be granted in the Class AA water of Kaneohe Bay or the West Loch of Pearl Harbor. In the nutrient deficient offshore waters, however, the addition of phosphorus can have very little detrimental effects and may be beneficial. Hence the reduction of estuarine eutrophication, where it is caused by phosphorus, can generally be accomplished much more readily by shifting phosphorus-rich effluents from the estuaries to well-designed ocean outfalls than by any other method.

This was pointed out in a 1971 legislative hearing on House Bill 297, which would ban phosphate-based detergents from Hawaii, by D. C. Cox, P. Helfrich, L. S. Lau, and R. H. F. Young, who based their views in part on the natural recycling possibilities in the ocean (a copy of their statement is attached). If nitrogen rather than phosphorus is the limitation to the productivity of surface ocean waters in the vicinity of the Hawaiian Islands, the addition of phosphorus in itself may not add to productivity, but the phosphorus so added may still be incorporated in the food chain by luxury consumption and hence be involved in natural recycling. In any case the additional phosphorus cannot be considered to have serious detriments in the open ocean.

7. Acknowledgments and limitations

The assistance of Dr. P. H. McGauhey and Dr. Reginald H. F. Young in preparing this statement is gratefully acknowledged.

Time has prevented the thorough review by marine biologists that the statement warrants. It will be sent to such experts for review, and any comments received will be forwarded later.

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9. Appendix

Phosphorus and phosphates are analyzed and reported in many ways. The analyses may include only dissolved inorganic forms of phosphorus, total dissolved phosphorus (inorganic plus organic), or total phosphorus including that in suspended particulates and plankton as well as that in solution. Concentrations may be expressed in terms of mass of phosphorus, mass-atoms of phosphorus, mass of orthophosphate ion, mass of phosphorus pentoxide, or mass of any of several phosphate compounds used in detergents. Some conversion factors to convert mass or mass-atomic concentrations to mass concentrations of phosphorus that may be useful are shown on the following page.

To convert

From concentrations expressed per unit vol. as			To g P per unit vol. multiply by
g	phosphorus	(P)	1.000
g at	phosphorus	(P at)	30.97
g	orthophosphate	(PO_4^{3})	0.1973
g	sodium tripolyphosphate	($Na_5P_3O_{10}$)	0.2526
g	tetrasodium pyrophosphate	($Na_4P_2O_7$)	0.2332
g	tetrapotassium pyrophosphate	($K_4P_2O_7$)	0.1937
g	trisodium phosphate	(N_3PO_4)	0.1892
g	phosphorus pentoxide	(P_2O_5)	0.4366

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Doak C. Cox, Ad interim Director
Environmental Center

[redacted]

L. Stephen Lau, Acting Director
Water Resources Research Center

[redacted]

John P. Craven, Dean
Marine Science Program

Table 1. Phosphate Concentrations Observed Estuarine Waters of Oahu.

Observer	Nature of Study	Location of Observation	PO_4-P* (mg/1)
Tseu (1952)	One-year study	Kaneohe Bay	0.0160 (max.)
	Most accurate 4 mos. of year	Kaneohe Bay	0.0090 (max.)
Piyakarnchana (1965)	One-year study during first year of sewage treatment	S.W. corner of Kaneohe Bay	0.0105 (initial) 0.0490 (final)
	plant discharge into Kaneohe Bay	S.E. of Coconut Island, Kaneohe Bay	0.0030 (initial) 0.0150 (final)
Bathen (1968)	13-month average over outfalls	outfall plume, City & Co. Kaneohe Sewage Tr. Plant	0.0443 (average)
	Kaneohe Bay	outfall plume, KMCAS Sewage Treatment Plant	0.0333 (average)
	13-month average	Kaneohe Bay	0.0099 (average)
Young et. al. (1969)	Survey of Kaneohe Bay	Middle of Kaneohe Bay	0.0020
		Northern portion of Bay	0.0060
		Over sewer outfall, southern portion of Bay	0.1000
Quan et. al. (1970)	Survey of Kaneohe Bay	-------------	0.0010
		Outfall plumes of sewage treatment plants	0.1000
			Total P mg/1
FWPCA (1969)	Observation Class AA water	Pearl Harbor, West Loch	0.0980**
	" " " A "	" " " "	0.0510**
	Surface and bottom	Middle and East Loch	0.0510 (average)
	Surface	Entrance channel	0.0340 (average)
	Bottom	" "	0.0240 (average)

* Phosphate Phosphorus. mg/1 ≃ 8.34 pounds per million gallons.
** Probably includes Phosphorus in suspended particulates.

Table 1. Phosphate Concentrations Observed Estuarine Waters of Oahu. (conted.)

Observer	Nature of Study	Location of Observation	PO_4-P* (mg/l)
Ultramar Chemical Co. (1968-1969)	Short-term studies for State Department of Health; Maui (total P)		
		Off west Maui	0.02180 (average)
		West Maui, shoreline	0.02890 (average)
		" " , offshore	0.01480 (average)
		Kahulili Bay area	0.14140 (average)
		" " shoreline	0.38530 (average)
		" " offshore	0.03320 (average)
Ultramar Chemical Co. (1968-1969)	Short-term studies for State Department of Health; Kauai (total P)		
		Kapaa-Nawiliwili area	0.03810 (average)
		" " shoreline	0.06760 (average)
		" " offshore	0.01980 (average)
		Koloa area	0.02220 (average)
		" shoreline	0.03240 (average)
		" offshore	0.01460 (average)
		Hanalei Bay area	0.03534
		" " shoreline	0.05230
		" " offshore	0.02690

* Phosphate Phosphorus. mg/l ≃ 8.34 pounds per million gallons.

UNIVERSITY OF HAWAII
ENVIRONMENTAL CENTER

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Review of HB 297

Relating to phosphate detergents

This report has been prepared by the undersigned who were appointed by the University of Hawaii Environmental Center to review the bill above named. Approval of its presentation does not imply an institutional position of either the Center or the University.

Synopsis

It is found that the right of the people to pure water shall not be abridged and that the phosphorus in synthetic detergents is an important water pollutant in Hawaii. It is the purpose of this bill to curtail the use of phosphorus by prohibiting the sale of phosphate containing detergents. Fines up to $500 per day are specified for violations of the prohibition.

Analysis

Phosphorus is correctly identified as a pollutant of major concern in Hawaiian waters, but the concern does not extend to all waters of the state, being restricted largely to coastal waters in areas of poor circulation. In such areas, such as Kaneohe Bay, phosphorus is suspected of being the principal pollutant responsible for a very extensive ecological change now in progress. Efforts to reduce the phosphorus discharge to Kaneohe Bay and similar areas are very worthwhile. In the surface layers of the open sea about Hawaii, however, phosphorus is a limiting factor to biological productivity, including fish, and consideration is being given even to the increase of phosphorus content for aquaculture in some areas, by pumping up the deeper water which is naturally phosphorus rich, or otherwise. Hence the detrimental effects of phosphorus in Hawaiian waters must be considered local rather than universal.

This situation is different from that pertaining in the inland waters of continental areas where the capabilities for the biological uptake of phosphorus and its immediate reincorporation in the biological cycle are much more limited than in the ocean.

Detergents are not the only source of phosphorus polluting coastal waters. Phosphorus is an essential constituent of most fertilizers used in commercial agriculture and home gardening. In some waters other sources of phosphorus are probably more important than the urban wastes carrying detergents, although data from Kaneohe Bay indicates that the treated sewage effluent is the major source of phosphorus there.

Means are available for the control of urban waste discharges containing phosphorus from detergents to the poorly mixed inshore waters by tertiary treatment, by use in irrigation on land, or by export to the open sea where mixing conditions are good and injection can be made below the surface layer.

Phosphorus is employed in the "builder" portion of synthetic detergents, as recognized in the bill. This is different from the "surfactant" portion with which there was environmental concern a few years ago because of the non-biodegradability of the original synthetic detergents, none of which are now on the commercial market. Recently some detergents have been manufactured using nitriloacetic acid (NTA) in place of phosphorus, but a probable health hazard associated with this material has led recently, according to press reports, to a federal ban on its use. Research is in progress to identify other materials that might be used to replace the phosphorus but, so far as we know, no satisfactory replacements have yet been identified. The natural soaps are generally much lower in phosphorus than the artificial detergents, but their virtual replacement, as noted in the bill, is an indication of their lower efficiency than the artificial detergents.

Considering these facts, a sensible decision to ban phosphate-based detergents would seem to depend upon the finding that certain environmental damages, those caused by that part of the phosphorus reaching inshore waters which is due to detergent usage and which is not amenable to changes in treatment or disposal location, are more important than the margin of efficiency of synthetic over natural detergents plus whatever environmental values may be associated with increases in phosphorus levels in waters of phosphorus deficiency.

Much more scientific and technological knowledge could be used in the quantification of the effects of phosphorus, both in the performance of the detergents and in the environment, but ultimately the decision must involve a value judgement that is philosophic or religious in nature, to which expert testimony is not directly pertinent.

If it is decided that the detriments associated with phosphorus-based detergents outweigh the advantages, and the sale of such detergents should be prohibited, should some agency not be empowered to enforce the prohibition and to assess the specified fines?

Incidentally, although the recognition of the right of people to pure water is most appropriate, this right, like all human rights cannot be considered an absolute one but one correlative with other basic rights. Environmental purity is an appropriate general goal, but one difficult to define, partly because life itself, as well as technology, is a source of pollution. Purity and naturalness may be distinguished from each other, and the intent of this bill is in reality focussed on naturalness rather than purity.

The definition of phosphorus in the bill leaves much to be desired from a technical standpoint.

Doak C. Cox, Ad interim Director, Environmental Center

Philip Helfrich, Acting Director, Hawaii Institute of Marine Biology

L. Stephen Lau, Acting Director, Water Resources Research Center

Reginald H.F. Young, Assoc. Professor, Civil Engineering & Public Health